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Ecological Research Series

INTERACTION OF OZONE AND HERBICIDES IN SOYBEANS

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Atrazine, metribuzin, and bentazon all affected transpiration. The transpiration of the ozone tolerant Hood cultivar was not affected by bentazon alone, but after treatment, transpiration increased significantly. The presence of atrazine residues in the soil decreased transpiration after ozone fumigation. In the ozone-susceptible Dare cultivar, bentazon inhibited transpiration, but following ozone fumigation there were significant differences. The cultivar Tracy proved to be very susceptible to metribuzin injury and was intermediate in sensitivity to ozone injury. It responded like Dare to bentazon alone, and like Hood following ozone fumigation.

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INTERACTION OF OZONE AND HERBICIDES IN SOYBEANS

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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report investigated the possibility of herbicides increasing ozone toxicity. An increased toxicity could significantly affect farming practices.

ABSTRACT

The purpose of this investigation was to identify potentially damaging herbicide-ozone interactions on soybean so that injury could be reduced by judicious selection of herbicides and tolerant cultivars. The involvement of herbicide influence on stomatal aperture affecting ozone fumigation injury was studied.

Soybean cultivars with varying sensitivity to ozone were planted in the greenhouse in soil containing residual levels of atrazine, normally recommended levels of metribuzin or nontreated soil. The herbicide bentazon was also studied, but was applied to foliage when the soybeans were 3 weeks old. After the soybean plants were in the second trifoliolate leaf stage or 3 to 7 days after bentazon treatment they were fumigated with 0, 0.3, or 0.4 ppm ozone. Transpiration rates were monitored to evaluate potential interactions.

Atrazine, metribuzin, and bentazon all affected transpiration. The transpiration of the ozone tolerant Hood cultivar was not affected by bentazon alone but after ozone treatment, transpiration increased significantly. The presence of atrazine residues in the soil decreased transpiration after ozone fumigation. In the ozone-susceptible Dare cultivar, bentazon inhibited transpiration, but following ozone fumigation there were significant differences. The cultivar Tracy proved to be very susceptible to metribuzin injury and was intermediate in sensitivity to ozone injury. It responded like Dare to bentazon alone, and like Hood following ozone fumigation.

This report was submitted in fulfillment of Contract No. R-803072 by Mississippi Valley State University. Under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period December 1, 1974, to March 31, 1977, and work was completed as of April 30, 1977.

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SECTION 1

INTRODUCTION

A number of soybean (Glycine max (L.) Merr.) production areas in the midwest and the south are located near large population centers and may experience exposure to ozone pollution. Ozone is the principal toxicant in photochemical smog and the most damaging air pollutant affecting vegetation in the United States (1). Soybeans and navy beans are relatively sensitive to ozone injury and such injury has been reported in the field due to acute ozone exposure because of inversion layers (2).

The vast majority of land (2,103,625 acres in Mississippi alone) currently in soybean production, especially in the south, is treated with preplant, preemergence, early post-emergence and/or late-directed herbicides. Up to four or five herbicides may be applied because of the long and favorable season for growth of crop and weed plants in the south. Although these herbicides may be selective, subtle effects of certain of these compounds on tolerant crops may occur. This is typified by the effect of atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) on the stomatal closing similar to antitranspirants which have been tested for this use (3). It is believed that ozone enters into the leaves through stomata to cause injury (4). Thus, compounds affecting transpiration could either increase or antagonize ozone injury. Conversely, ozone has been shown to alter metabolism rate of the herbicide diphenamid (N,N-dimethyl diphenylacetamide) in plants (5). In the United States over 40,000,000 acres of soybeans are planted annually. Even a slight decrease in yield as a result of ozone damage or an interaction of ozone and herbicides would be manifested in tons of protein which could otherwise be used for human and animal consumption.

Numerous research papers have reported the interactions of the factors such as pesticides, temperature, soil moisture, fertilizer types, cultivar differences, and agronomic practices in altering the use of herbicides. An environmental factor which has received only recent attention in relation to cultivar differences and herbicides interactions is ozone (6). The purpose of this proposed research was to study the interactions of herbicides and acute levels of ozone as they might alter the sensitivity of soybean cultivars. Soybean cultivar differences in response to acute ozone dosage were demonstrated by Tingey and et al. (2). Ozone under laboratory conditions has been reported to induce stomatal closure (1). Stomatal closure in ozone treated oats depressed photosynthesis and reduced transpiration. The purpose of this investigation was to:

(A) Assess the extent of ozone-herbicide interaction and thus reduce damage to soybeans by selecting herbicides and tolerant cultivars and;

(B) Study the behavior and resistance of the stomata as port of entry of ozone and consequent effect on transpiration and growth of soybean plants.

SECTION 2

CONCLUSIONS

Although ozone enters through the stomata it did not appear to affect transpiration three days after exposure. Thus, measuring transpiration for several days after ozone fumigation is not the most sensitive way of evaluating ozone injury. However, the herbicides bentazon, atrazine, and metribuzin all affected transpiration and in the case of bentazon, subsequent ozone fumigation increased transpiration, indicating a possible bentazon-ozone interaction. The three cultivars studied did not accrue leaf area at exactly the same rate, consequently evaluation of transpiration was more accurate when the rates were based on the pretreatment rate and expressed as a percentage of that rate. The duration of the experiments was too short to use changes in leaf area as a criteria for either ozone or herbicide injury.

Interestingly, the transpiration rate of the three cultivars appeared to be almost identical on a leaf area basis. Thus, the differential sensitivity of the three cultivars to ozone does not appear to be related to transpiration differences that could have reflected differences in density of stomatal distribution.

SECTION 3

RECOMMENDATIONS

The data presented in the report suggest that herbicide-ozone interaction may occur. Measurement of transpiration appears rather insensitive to early evaluation of interaction responses. Thus, future studies should be less difficult to interpret if limited to the study of the bentazon-ozone interaction and the use of a more sensitive measurement to detect the interaction response. Studies by Tingey et al (7) would suggest that measurement of ethylene release would be more sensitive and appropriate to measure the initial response. This should be followed by obtaining fresh weight, dry weight, and plant height data over a time period following fumigation. The basis for the observed action should be pursued. This knowledge could have predictive value in identifying other ozone-related interactions potentially reducing soybean production.

SECTION 4

MATERIALS AND METHODS

TEST PLANTS

Three soybean (Glycine max (L.)Merr.) cultivars primarily grown in the south were selected for this investigation. They were Dare, maturity Group V, selected because of its relative susceptibility to ozone damage (2); Hood, maturity Group VI, selected because of its relative tolerance to ozone damage (2); and Tracy, maturity Group VI, selected because it was relatively tolerant to herbicide 2,4-DB (8), a recent introduction with very desirable characteristics, but its susceptibility to ozone damage was not known.

PLANT GROWTH CONDITIONS

Fungicide (spergon) treated seeds of each cultivar, one seed each per 170 g styrofoam cup were planted in 100 oven-dried loamy sand soil that contained 73% sand, 12.5% silt, 14.5% clay and approximately 0.4% organic matter. Each cup of soil was brought to field capacity moisture level by weighing and adding water to each cup immediately after seeding. The plants were randomly placed in a greenhouse with temperatures of 24 $\pm$ 5°C during day and 13 $\pm$ 5°C during night with 75 $\pm$ 15% relative humidity. The greenhouse lighting was supplemented for 6 hr/day with Sylvania grolux tubes during short days. The light intensity was recorded by Lambda light meter model no. LI-170 and photometric sensor LI-2105. The plants were checked every day for loss of moisture by weighing and watered to field capacity. The plastic lids were placed on the cup around the plants after the seedling had grown to reduce the soil surface water loss by evaporation. The nutrients in the soil maintained satisfactory growth of plants for the duration of the experiments from three to five weeks. The plants were not fertilized to avoid a possible interaction between nutrients and the treatments.

HERBICIDE TREATMENT AND OZONE FUMIGATION

Three herbicides, atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine), bentazon (3-isopropyl-1H-2,1,3-benzothiodizin-4(3H)-one 2,2-dioxide), and metribuzin (4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H) one) were selected for the interaction study with ozone. Atrazine, reported to decrease stomatal aperture and reduce the transpiration rate, was incorporated into the soil mix at 0, .07, .14, .28, .56, or .84 kg/ha to simulate residues that might be present in a soybean-corn rotation. Bentazon, a postemergence herbicide, was applied at 0, 0.56, 0.84 or 1.1 kg/ha when the soybeans were 3 weeks old, had three trifoliate leaves, and a Plastochron Index (P.I.) of 3.5. The P.I. provided a numerical evaluation of leaf age, leaf development, and the physiological maturity of the plant useful for comparing growth stage of plants (Tingey, D.T., 1974 Personal communication). Metribuzin was incorporated into the soil prior to planting at rates of 0, 0.14, 0.28, or 0.56 kg/ha. Herbicide application rates were determined by adjusting pressure on the nozzle and speed of the conveyor belt carrying the

plants under the stationary nozzle.

The plants of the three cultivars were exposed to ozone concentrations of 0, 0.3, or 0.4 ppm for 2 hr in chambers previously described (9). Ozone was generated by controlling the flow of dry oxygen through a Sanders' Ozonizer with an output of 0.50 mg/hr. The ozone concentration within the chamber was measured with a Mast-ozone meter (model 724-2) interfaced with a recorder. During fumigation the light intensity was 35 $\pm$ 5 klux, the temperature was 17 $\pm$ 2°C, and the relative humidity was 85 $\pm$ 3% inside and outside the chambers in the greenhouse. In the first study, the plants were fumigated 7 days after bentazon application; in the second study, 3 days after bentazon application.

TRANSPIRATION RATE MEASUREMENT

Changes in transpiration rate were used to assess plant injury due to ozone, the herbicides, or the combination of both. In several studies, rates were also compared to prevailing rates prior to herbicide and ozone treatment. The water loss by plants was determined by weighing each cup every day and adding enough water to the soil so as to bring it up to the original predetermined field capacity moisture level. As the plants grew older the predetermined weight of the cup was revised upwards periodically.

The leaf surface area was also measured in some experiments with leaf area meter Lambda model no. LI-3000. Transpiration rate and leaf surface area provided the basis for expressing the rate of transpiration in terms of weight/area/time.

The plants of the three cultivars were indexed for ozone and herbicide visual injury on a scale ranging from 0 to 100, 4 days after treatment. The injury estimates were made for each trifoliate leaf of the plant and then grouped and averaged for the whole plant. The 0 was for undamaged leaf and 100 for dead leaves. Cultivars Dare and Hood were treated with 1.1 kg/ha bentazon followed with 0.4 ppm ozone fumigation after 3 days and photographed 5 days later for the visual injury scoring.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

The uniformly selected plants were placed in the greenhouse and in the fumigation chambers according to a randomized complete block design with four to eight replications. The data were statistically analyzed by analysis of variance program by computer at Michigan State University. The significant differences among means of the treatments were determined using Duncan's Multiple Range Test. Herbicide treatments were considered as the main plots, while cultivars and ozone concentrations as the sub-sub plots with a given number of replications in three way factorial experiments.

SECTION 5

RESULTS AND DISCUSSION

It is generally agreed that ozone enters the plant leaf through the stomata and that oxidant injury occurs first in the vicinity of penetration. In a study to determine whether ozone influenced transpiration in the ozone susceptible Dare cultivar, the tolerant Hood, or Tracy cultivar with or without a bentazon treatment 7 days earlier, the results indicated little or no effect of ozone on transpiration (Table 1). Only the Tracy cultivar in the absence of a bentazon treatment showed a slight but significant increase in transpiration. From these results one might speculate that modest levels of ozone pollution do not increase moisture stress on the total plant although the topical or localized effect is severe. In this study the transpiration data are based on the transpiration of the particular plant prior to herbicide or ozone treatment. No differences in transpiration were observed among the three cultivars averaged over all other treatments. The experiment showed that bentazon at 1.1 kg/ha inhibited transpiration when other factors were not considered. This expected result confirmed the previous report of Penner (10) that bentazon rapidly inhibits transpiration. However, the data from this study show two additional interesting features. First, following ozone treatment, the water loss picture is reversed and secondly that the cultivars do not respond similarly. The transpiration of the ozone tolerant Hood was not affected by bentazon alone but after the ozone treatment, transpiration increased significantly. In the susceptible Dare, the bentazon inhibited transpiration, but following ozone fumigation there were no significant differences. Visual injury ratings indicated a bentazon-ozone interaction for Dare but not Hood (Figure 1). Tracy seems to be an intermediate in susceptibility to ozone injury and responded like Dare to bentazon treatment alone and responded like Hood following ozone fumigation. In a repeat experiment, bentazon failed to inhibit transpiration in Dare prior to fumigation but did stimulate transpiration again of Tracy at the 0.56 kg/ha rate. The response of Hood in the repeat experiment was similar to that reported in Table 1.

In a second study, the application of 0.84 kg/ha of bentazon markedly inhibited transpiration of all three cultivars. This was still evident after ozone fumigation (Table 2). The Tracy cultivar showed less inhibition than Dare or Hood. The Hood cultivar appeared to have significantly lower transpiration than the other two cultivars.

In additional experiments with eight replications and application of 0, 0.50, and 1.12 kg/ha of bentazon to the three soybean cultivars the Hood cultivar again had significantly less transpiration than Dare on a per plant basis. However, in this experiment, leaf areas were measured and conversion of transpiration to grams water lost per cm^2 per 24 hr showed Dare, Hood, and Tracy to have values of 0.131, 0.138, and 0.131, respectively. Thus the decreased transpiration of Hood cultivar in Tables 2 and 3 is merely a

reflection of less leaf area, confirming the results presented in Table 1 indicating no difference among cultivars in transpiration rate.

Soybeans frequently follow corn in the crop rotation. It is not unusual for low levels of atrazine to persist into the following year if the weather has been cool and dry during the treatment year. Ladlie et al. (11) showed that low levels of atrazine stimulated, whereas higher levels inhibited transpiration. The data obtained in this study (Tables 3 and 4) failed to show the stimulation of transpiration by low rates of atrazine but did show inhibition of transpiration at the 0.84 kg/ha rate.

In 1975 low levels of metribuzin acted similarly to atrazine; however, in 1976, 0.28 kg/ha of metribuzin significantly stimulated transpiration (Table 5). The cultivar Tracy appeared to be much more susceptible to metribuzin injury than the other cultivars.

Metribuzin did not appear to interact with ozone fumigation to affect transpiration (Table 6), whereas in another study the presence of 0.14 kg/ha of atrazine in the soil appeared to interact with the ozone fumigation to reduce transpiration (Table 7). These results could have occurred if ozone fumigation initially caused an increase in water loss resulting in increased atrazine uptake. The increased atrazine caused stomatal closure and consequent decreased water loss of transpiration.

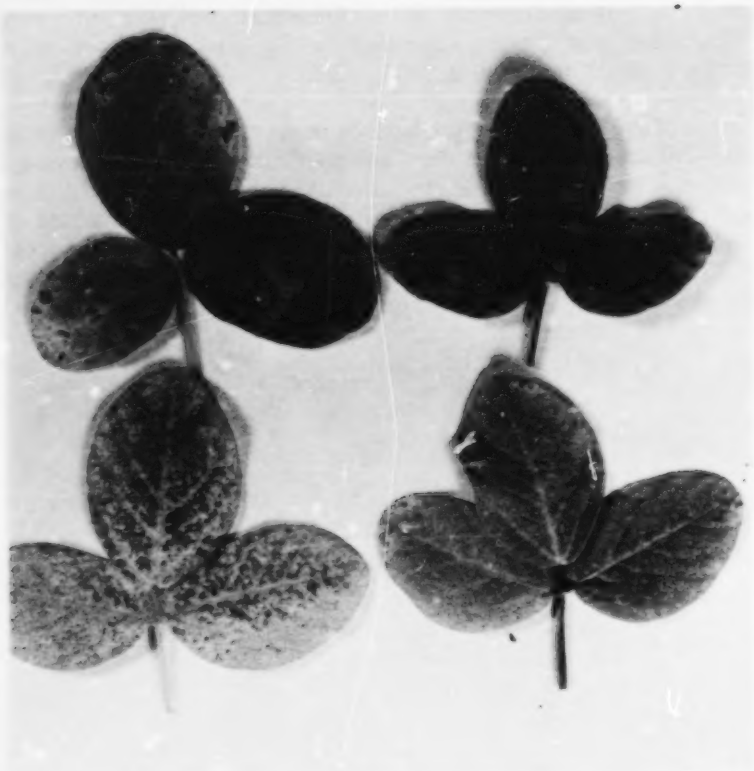

Figure 1. Top left, Dare treated with 1.12 kg/ha bentazon and 0.0 ppm ozone. Visual injury 30-35%. Bottom left, Dare treated with 1.12 kg/ha bentazon and 0.40 ppm ozone. Visual injury 75-80%. Top right, Hood treated with 1.12 kg/ha bentazon and 0.0 ppm ozone. Visual injury 25-30%. Bottom right, Hood treated with 1.12 kg/ha bentazon and 0.40 ppm ozone. Visual injury 35-40%.

TABLE 1. THE INFLUENCE OF BENTAZON, CULTIVARS, AND OZONE LEVELS ON TRANSPIRATION OF 3-WEEK-OLD SOYBEAN

Bentazon Rate (kg/ha)	Cultivar	Ozone Level (ppm)	Transpiration[a] March	
			6 days after bentazon treatment (% of base rate)	3 days after o-zone fumigation (% of base rate)
0	Dare	0	99 cd	139 bcd
	Dare	.4	90 abcd	124 abc
	Hood	0	88 abc	116 ab
	Hood	.4	93 abcd	138 bcd
	Tracy	0	92 abcd	110 a
	Tracy	.4	97 bcd	142 bcd
.56	Dare	0	92 abcd	131 abcd
	Dare	.4	90 abcd	142 bcd
	Hood	0	94 abcd	138 bcd
	Hood	.4	83 a	130 abcd
	Tracy	0	100 cd	155 d
	Tracy	.4	101 d	149 cd
1.12	Dare	0	84 ab	143 bcd
	Dare	.4	83 a	136 abcd
	Hood	0	92 abcd	151 cd
	Hood	.4	82 a	142 bcd
	Tracy	0	84 ab	150 cd
	Tracy	.4	85 ab	142 bcd
Effect of bentazon averaged over cultivar and ozone levels				
0			93 b	128 a
.56			93 b	141 b
1.12			85 a	144 b
Effect of bentazon x varieties averaged over ozone levels				
0	Dare		94 bc	132 ab
.56			91 ab	137 abc
1.12			84 a	139 abc
0	Hood		90 ab	127 a
.56			88 ab	134 abc
1.12			87 ab	147 bc
0	Tracy		95 bc	126 a
.56			101 c	152 c
1.12			84 a	146 bc

(continued)

Table 1 (continued)

Bentazon Rate (kg/ha)	Cultivar	Ozone level (ppm)	Transpiration[a] March 6 days after bentazon treatment (% of base rate)	Transpiration[a] March 3 days after ozone fumigation (% of base rate)
Effect of ozone average over cultivars and bentazon levels				
		0	92 a	137 a
		.4	89 a	138 a
Effect of cultivar averaged over all bentazon and ozone levels				
	Dare		90 a	136 a
	Hood		89 a	136 a
	Tracy		93 a	141 a

[a]Means within columns with similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

TABLE 2. THE INFLUENCE OF BENTAZON, CULTIVARS, AND OZONE LEVEL ON WATER LOSS FROM 3-WEEK-OLD SOYBEAN.

Bentazon Rate (kg/ha)	Cultivar	Ozone Level (ppm)	Water Loss (3 day average) after ozone fumigation[a] (gm/plant)
0	Dare	0	4.5 d
		.4	4.4 cd
	Hood	0	4.0 bc
		.4	3.9 b
	Tracy	0	4.4 cd
		.4	4.8 d
.84	Dare	0	2.4 a
		.4	2.7 a
	Hood	0	2.7 a
		.4	2.5 a
	Tracy	0	3.6 b
		.4	3.6 b
Effect of bentazon averaged over cultivars and ozone levels			
0			4.3 b
.84			2.9 a
Effect of cultivars averaged over bentazon and ozone levels			
	Dare		3.5 b
	Hood		3.2 a
	Tracy		4.1 c
Effect of bentazon x cultivars averaged over ozone levels			
0	Dare		4.5 d
.84			2.5 a
0	Hood		3.9 c
.84			2.6 a
0	Tracy		4.6 d
.84			3.6 b

[a]Means within columns with similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

TABLE 3. THE INFLUENCE OF SIMULATED ATRAZINE RESIDUE LEVELS ON THE TRANSPIRATION OF THREE CULTIVARS OF 3-WEEK-OLD SOYBEAN.

Atrazine Rate (kg/ha)	Cultivar	Transpiration[a] (gm/plt/24 hr)
0	Dare	8.7 d
	Hood	8.2 bc
	Tracy	8.5 cd
.07	Dare	8.8 d
	Hood	8.0 ab
	Tracy	8.7 d
.14	Dare	8.6 d
	Hood	7.8 a
	Tracy	8.5 cd
Effect of atrazine averaged over all three cultivars		
0		8.5 a
.07		8.5 a
.14		8.5 a
Effect of cultivars averaged over all atrazine three levels		
	Dare	8.7 b
	Hood	8.0 a
	Tracy	8.5 b

[a]Means within columns with similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

TABLE 4. THE INFLUENCE OF ATRAZINE ON THE TRANSPIRATION AND LEAF AREA OF THREE CULTIVARS OF 3-WEEK-OLD SOYBEAN

Atrazine Rate (kg/ha)	Cultivar	Transpirational Water Loss[a] (g/plt/24 hr)	Leaf Area[a] (cm^2/plt)
0	Dare	10.0 cde	81.1 a
	Hood	10.1 cde	87.2 a
	Tracy	10.2 de	83.2 a
.28	Dare	10.0 cde	86.6 a
	Hood	9.8 bcd	89.9 a
	Tracy	10.2 de	85.4 a
.56	Dare	10.3 e	78.4 a
	Hood	10.0 cde	82.4 a
	Tracy	9.7 abc	69.0 a
.84	Dare	9.5 a	-
	Hood	9.4 a	-
	Tracy	9.4 a	-
Effect of atrazine averaged over all three cultivars			
0		10.0 b	83.9 a
.28		10.0 b	97.3 a
.56		10.0 b	76.6 a
.84		9.4	-

[a]Means within columns with similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

TABLE 5. THE INFLUENCE OF METRIBUZIN ON TRANSPIRATION AND LEAF AREA OF THREE CULTIVARS OF 3-WEEK-OLD SOYBEAN.

Metribuzin Rate	Cultivar	Experiment I Transpiration[a] (g/plt/24 hr)	Leaf area[a] (cm^2/plt)	Experiment II Transpiration[a] (g/plt/24 hr)
0	Dare	10.0 cde	81.1 ab	8.7 b
	Hood	10.1 cde	87.2 abc	8.2 a
	Tracy	10.0 cde	83.2 abc	
.14	Dare	10.3 de	94.3 c	
	Hood	9.9 cd	93.8 c	
	Tracy	10.6 e	90.9 bc	
.28	Dare	10.0 cde	88.2 bc	9.6 c
	Hood	9.6 cd	86.3 abc	8.4 ab
	Tracy	8.8 b	Dead	
.56	Dare	9.6 cd	82.8 abc	8.3 ab
	Hood	9.5 c	75.6 a	8.1 a
	Tracy	7.1 a	Dead	
	Effect of metribuzin averaged over all three cultivars			
0		10.0 c		8.5 a
.14		10.3 c		
.28		9.5 b		9.0 b
.56		8.7 a		8.2 a

[a]Means within columns with similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

TABLE 6. THE INFLUENCE OF METRIBUZIN AND OZONE ON THE TRANSPIRATION OF 3-WEEK-OLD SOYBEAN

Metribuzin Rate (kg/ha)	Cultivar	Ozone Level (ppm)	Transpiration[a] (% of rate prior to fumigation)
0	Dare	0	82.4 a
		.3	86.1 a
		.4	89.3 a
	Hood	0	92.1 a
		.3	86.7 a
		.4	86.4 a
.56	Dare	0	95.3 a
		.3	85.1 a
		.4	86.3 a
	Hood	0	97.0 a
		.3	81.1 a
		.4	80.9 a

[a]Means with similar letters are not significantly at the 5% level by Duncan's Multiple Range Test.

TABLE 7. THE INFLUENCE OF ATRAZINE AND OZONE ON THE TRANSPIRATION OF 3-WEEK-OLD SOYBEAN

Atrazine Rate (kg/ha)	Cultivar	Ozone Level (ppm)	Transpiration[a] (% of rate prior to fumigation)
0	Dare	0	82.4 abc
		.3	85.1 abc
		.4	89.3 abc
	Hood	0	92.1 bc
		.3	86.7 abc
		.4	86.4 abc
	Tracy	0	94.6 bc
		.3	70.7 a
		.4	83.6 abc
.14	Dare	0	91.1 bc
		.3	92.0 bc
		.4	80.4 ab
	Hood	0	101.9 c
		.3	83.6 abc
		.4	70.0 a
	Tracy	0	91.4 bc
		.3	86.9 abc
		.4	78.4 ab
Main effect of ozone averaged over cultivars and atrazine rates			
		0	92.3 b
		.3	84.2 a
		.4	81.4 a
Main effect of cultivars averaged over ozone and atrazine rates			
	Dare		86.7 a
	Hood		86.8 a
	Tracy		84.3 a
Main effect of atrazine averaged over ozone and cultivars			
0			85.7 a
.14			86.2 a

(continued)

TABLE 7 (continued)

Atrazine Rate (kg/ha)	Cultivar	Ozone Level (ppm)	Transpiration[a] (% of rate prior to fumigation)
		Atrazine-ozone interaction averaged over all cultivars	
0		0	89.7 bc
		.3	80.9 ab
		.4	86.4 abc
.14		0	94.8 c
		.3	87.5 bc
		.4	76.3 a

[a]Means with similar letters are not significantly different by Duncan's Multiple Range Test.

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